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Hull, Mechanical, & Electrical (HM&E) Roadmap: Revolutionizing Naval Warfare and Achieving Energy Security

ABSTRACT

The United States Navy faces the challenge of meeting increasing electrical power demands for advanced sensors and weapons while reducing vulnerability associated with a dependence on foreign sources of petroleum. As the technological sophistication of ballistic and anti-ship cruise missiles increases and their proliferation expands, the fielding of enhanced sensor and weapon system capabilities is required. Further, the evolution of asymmetric threats requires new technology solutions for lethal and non-lethal shipboard defense systems. Several emerging technologies will be introduced over the next several years to enhance mission capabilities. High-power lasers will provide a directed energy engagement element to augment the U.S. Navy's Close-In Weapon System with defensive capability to counter several asymmetric threats and provide enhanced lethality. Hypersonic technologies, such as the electro-magnetic railgun, will deliver long-range, precision volume fires, increase stand-off range, and decreased time-to target. Innovative technologies will be required to increase energy efficiency and satisfy electrical power demands for advanced sensors and weapons. One of the ways the naval engineering community will lead the drive toward energy reform and meet increasing electric power demands is through the early adoption of energy-efficiency enabling technologies. Plans are underway to field new technologies such as solid state lighting, stern flaps, and Hybrid Electric Drive (HED) to meet increasing power demands, enhance operational flexibility, and support forward presence, while reducing the susceptibility inherent in a long energy supply line tether. The U.S. Navy has developed and reformed its energy policy in recent years to leverage the investments in energy efficient technologies to support the Chief of Naval Operations (CNO's) energy vision. There are many challenges associated with incorporating new technologies into current and future ship designs. One approach to more efficiently address these challenges is an integrated Hull, Mechanical, and Electrical (HM&E) Roadmap to support the revolution in naval warfare and achieve an energy secure future.

INTRODUCTION

> *"Our ships – the systems that we use and the power requirements that they have are getting bigger all the time. Every system we're putting on a ship or in our aircraft is in some ways sort of a power hog. Just like the commercial world, the march of technology in the military has created an ever-increasing appetite for energy… we have to find a different way to power the things we need to power."*
>
> Secretary Ray Mabus
> 75th United States Secretary of the Navy
> 2011 ARPA-E Innovation Summit

Energy security has become a strategic as well as an operational imperative for the world's navies. New approaches and innovative technologies are required to significantly improve fuel efficiency, increase endurance, enhance operational flexibility, and support forward presence while reducing vulnerability inherent in a long supply line tether. Assured access to reliable and sustainable supplies of energy is central to the U.S. Navy's ability to meet operational requirements globally, whether keeping the seas safe from pirates operating off the coast of Africa, providing humanitarian assistance in the wake of natural disasters in the Pacific, or delivering counter-terrorism and special mission unity to hostile regions in the Middle East. From both a strategic and operational perspective, the call to action is clear. Rapid employment of energy efficient technologies and strategic development of energy efficient technologies and architectures are required to transform the U.S. Navy's energy security posture while meeting increasing electric power demands for enhanced combat capability.

Beyond the strategic and tactical implications cited above, extreme volatility of oil prices and the cost to provide persistent maritime presence required to ensure access to foreign fuel supplies presents a significant

challenge for the U.S. Navy. Between 2003 and 2009, the global oil market witnessed its most significant period of volatility in decades (U.S. Energy Information Administration 2010). After relentlessly increasing, oil prices reached a historic high of more than $147 per barrel in July 2008 (BP plc. 2011). Oil prices retreated to less than $40 per barrel following the global economic crisis in early 2009, but consistently climbed over the next two years, averaging the second highest level on record in 2010 (BP plc. 2011), and breaking $100 per barrel throughout most of 2011 (U.S. Energy Information Administration 2011). Unpredictable fuel prices exacerbate fiscal challenges faced by the U.S. Navy, which contributes to more than one-third of the Department of Defense's $20 billion for 135 million barrels of fuel consumed annually (Department of Defense Energy Security Act of 2011). Further, recent economic studies have employed full-cost accounting methods (Kaplan 2011) to estimate the costs force projection in the Persian Gulf, including the cost for the U.S. Navy to maintain a carrier battle group in the region (Stern 2010). These studies, sponsored by Princeton University's "Oil, Energy, and the Middle East" program, estimate the cost of sustained operations over the thirty-year period of nearly $7 trillion dollars (Stern 2010) - approximately one-half of the current U.S. National Debt (Congressional Budget Office January 2011). It is important to note, the cost to maintain a military force projection throughout the Persian Gulf region represents a fraction of total burden to maintain energy security (Greene 2010) as the U.S. Navy provides persistent presence supporting global trade and maritime commerce for millions of barrels of oil each day (Gallagher 2011).

Finally, continuing the efficiency gains realized over the past few years will become more challenging as the initial list of "low hanging fruit" is consumed. Recent equipment-level efficiency gains have typically been identified as form, fit, and functional equivalent units. As these initiatives are realized, the U.S. Navy will need to turn to more complex system-level improvements with larger ship integration impacts to achieve aggressive fossil-fuel reduction goals set over the next decade. These challenges, coupled with shorter ship development cycles and longer development timeframes for new and innovative technology, exacerbate the U.S. Navy's issues and underscore the need for a well-defined roadmap to mobilize support for fundamental HM&E improvements and drive alignment across organizations, while also leveraging technology and system level investment across platforms.

Considering the challenges facing the U.S. Navy and its Fleet of Surface Ships, this paper addresses the fundamental questions identified in Fig.1, proposing a disciplined framework bridging legislation into operations to deliver smarter HM&E solutions for an affordable, energy secure Fleet. Specifically, this paper introduces a means to evaluate and map technologies that lay a foundation to transform the U.S. Navy's energy posture and provide an effective means of delivering additional power for advanced sensor and future weapon systems of tomorrow.

Strategy	What are the ways U.S. Navy Surface Ships can enhance National Security to meet operational requirements globally?
Measurement	What are measureable drivers which define success in achieving SECNAV and CNO strategic objectives?
Analysis	What are the ways the U.S. Navy performs objective analysis to identify candidate HM&E technologies?
Redesign	What are the opportunities to rebalance near and long-term HM&E technology portfolios required to execute the strategy?
Transformation	How will the U.S. Navy sustain results over the long-haul and integrate engineering changes into the acquisition process?

FIGURE 1 Five Disciplines Bridging Legislation into Operations

STRATEGY

Energy as a strategic resource

The U.S. Navy is working to enhance national security by reducing warfighter dependence of vulnerable fuel supplies while simultaneously ensuring surface ships are able to meet the increasing electric power demand as they continue to pace the threat well into the twenty-first century (Greenert 2011). Vulnerabilities presented by the volatility of energy costs, dependence on limited foreign oil sources, and an increasing threat of foreign energy suppliers attempting to influence our economy all address the need to transform energy supply, demand, and security for the U.S. Navy. Deliberate, strategic measures to mitigate this operational impact on Fleet petroleum fueled surface ships have become a priority to ensure that ships are available for tasking and can remain

on station. Clearly, energy has a direct impact on warfighting effectiveness, and energy security has become a strategic and operational imperative for the world's navies. Operating in today's fiscally constrained environment over the next decade will continue to magnify the impact of the U.S. Navy's dependence on foreign and non-renewable sources of energy. For every dollar increase in the price of a barrel of oil, U.S. Navy annual fuel costs rise by nearly $31 million (Hsu 2011). In June 2011, the Defense Logistics Agency (DLA) increased Department of Defense (DoD) standard fuel prices by $39, resulting in an unplanned increase of $562 million over the next year for the U.S. Navy (McDermott 2011). While the global financial crisis has driven oil from record prices set during the summer of 2008, the U.S. Navy has not lost momentum in its efforts to field an energy secure Fleet of the future and has identified a set of aggressive goals for the service to meet over the next decade (Morello 2010).

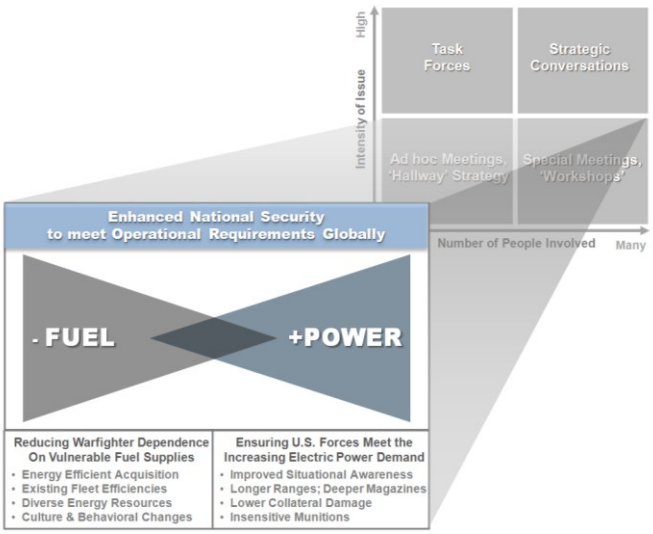

FIGURE 2 Reshaping the Strategic Planning Process

Surface ships' energy requirements account for approximately forty percent of the total U.S. Navy fuel budget. Taxing ship maintenance accounts because of rapid rises in fuel costs and no relief in the Fleet's operating tempo has put the material condition of the Fleet at risk. This business model impairs the ability of our ships to train and become proficient in their mission area skills. As a result of the rapid increase in fuel costs in 2008, the CNO established a Task Force to provide governance and structure to manage the U.S. Navy's energy policy, including a Maritime Working Group (MWG) chartered to identify and implement ways to reduce surface ship fuel consumption (Truver et al. 2011). In order to mitigate the risks of energy price and foreign fossil fuel dependence, the MWG developed strategies to reduce energy demand and increase alternative energy supplies for U.S. Navy surface ships. The MWG has aligned efforts with the overall U.S. Navy Energy Strategy to increase operational independence, improve efficiency, and decrease overall fuel consumption. Moving forward, the cross-disciplinary members of the Task Force working groups have worked to increase energy awareness and conservation, raise the visibility of energy in budgeting and acquisition, and advance the right initiatives to promote efficiency in U.S. Navy energy use (Fig. 2). Reshaping the traditional strategic planning process (Beinhocker 2002) and significantly expanding initial task force activities has produced strategic and operational advantages for critical U.S. Navy energy security initiatives (Friedman 2010).

TABLE 1 U.S. Navy Energy Strategy

CNO Guidance: Provide a Navy Energy Strategy that treats energy as a strategic resource			
Ends	**Ways**		**Means**
Vision	**Strategic Imperatives**	**Targets**	**Enablers**
• A Navy that values energy as a strategic resource • A Navy that understands how energy security is fundamental to executing our mission afloat and ashore • A Navy resilient to any potential energy future	• Assure Mobility • Protect Critical Infrastructure • Lighten the Load • Expand Tactical Reach • Green Footprint	• Increase Alternatives Afloat • Sail the Great Green Fleet • Increase Alternative Energy Ashore • Reliable Power for Critical Infrastructure • Reduce Non-Tactical Petroleum Use • Increase Efficiency Afloat • Increase Efficiency Ashore • Energy Efficient Acquisition	• Leadership • Technology • Policy • Strategic Partnerships • Culture Change

To help offset the financial impact of oil prices, the U.S. Navy leadership issued a set of aggressive goals to significantly reduce dependence on foreign oil by 2020. In October 2009, the Secretary of the U.S. Navy (SECNAV) outlined specific objectives (Table I), including several aimed at increasing energy efficiency while accelerating the adoption of renewable sources of energy to support the deployment of a "Green Strike Group" in 2012. To this end, the U.S. Navy has

undertaken efforts to mature and insert numerous energy efficient technologies in the near-term including new efficient ship systems, improved hydrodynamics, and innovative integration concepts such as HED. Longer-term technology development strategies include the adoption of Advanced Naval Power Systems throughout the Surface Fleet to provide integrated ship electric power (Petersen et al. 2010). Several other long-term development strategies for HM&E systems extend over a decade or more. Historically, maritime energy programs have encountered funding challenges, particularly a lack of sufficient funding to transform energy technologies into efficient shipboard systems which are ready to be included in ship construction and modification. This reality has impeded significant technology development for energy efficiency gains. These systems require significant investments from early science and technology through development funding, long before ship parameters are defined. The HM&E Roadmap will promulgate the technology design strategy to cultivate widespread support, promote constructive debate, and communicate the often longer than expected development timelines to support new technologies for future ship designs.

MEASUREMENT

Identifying the Requirement

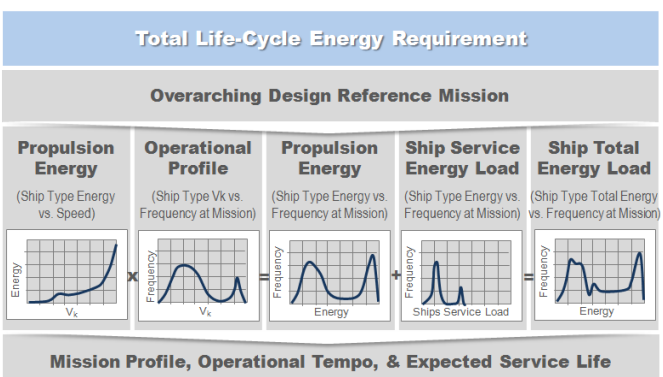

FIGURE 3 Identifying the Gap to Meet Operational Requirements

The U.S. Navy Surface Fleet is projected to grow to as many as 170 ships by 2020 (Congressional Budget Office May 2011). The need to project and manage the fuel budgets and overall consumption for the Fleet is paramount in order to maintain flexible and efficient warfighting capabilities (Fig. 3). The U.S. Navy has recently restarted the production line for DDG 51 Class Guided-Missile Destroyers, authorized the acquisition of two Littoral Combat Ship variants, and expanded the role of the effective and highly adaptable nature of amphibious warfare ships (Congressional Budget Office May 2011). The engineering plant designs of these ships, combined with their high operating tempo, contribute to a trend of growing fuel consumption demand (Congressional Budget Office June 2011). U.S. Navy Surface Ships are traditionally designed with maximum combat capability and range as requirements, where fuel consumption rates are a secondary function of operating ability compared to an allowable maximum consumption (Congressional Budget Office June 2011). In October 2010, the CNO outlined a vision of a Navy that values energy as a strategic resource, a Navy that understands how energy security is fundamental to executing mission objectives, and a Navy that is resilient to any potential energy future (Truver and Holzer 2011). As part of these goals, the U.S. Navy plans to significantly reduce non-renewable fossil fuel, with a goal of obtaining 50 percent of energy consumption from alternative sources (Roughead 2010).

Running counter to these goals, the amount of electrical power used aboard Surface Ships has grown exponentially over the past century and is expected to continue in the near future (Petersen 2011). As the technological sophistication of ballistic and anti-ship cruise missiles increases and they continue to proliferate, the fielding of enhanced sensor and weapon system capabilities is required. The evolution of asymmetric threats requires new technology solutions for lethal and non-lethal shipboard defense systems. Several high-energy weapon technologies will be introduced over the next several years to enhance mission capabilities (Table 2), and power requirements will rise (O'Rourke 2011).

The Surface Warfare community will require an integrated approach to satisfy increasing shipboard power demands and high operational tempo while improving energy efficiency and expanding the adoption of renewable energy sources. To meet this need in support of the warfighter, there must be a fundamental paradigm shift from traditional to integrated architectures (Amy 2005). This will close the affordability gap, enabling access to all installed power to increase available power at a lower cost while maintaining mission capability.

TABLE 2 Advanced Sensors and Future Weapons

Naval Capability	Description
Advanced Sensors	Next generation scalable, multi-mission radar system planned for future combatants; comprised of an X-band and S-band radar. • Intended to provide unprecedented situational awareness • Detect, track, and engage ballistic missiles in high clutter environments • X-band radar provides horizon search, precision tracing, and final illumination guidance to targets • S-band provides wide-area volume search, tracking Ballistic Missile Defense (BMD) discrimination, and missile communication
Directed Energy	Effective and affordable point defense capability against many surface/air threats, Anti-Ship Cruise Missiles (ASCMs), ballistic missiles, swarms of small boats, and/or UAVs. • Graduated Lethality • Lower per engagement and life cycle costs • Precise engagement/low collateral damage • Rapid reaction to moving or swarming targets
Hypersonic Technologies	Fully electric weapons, such as the Electromagnetic Railgun will be capable of launching projectiles 200 nautical miles • Delivers long-range, precision volume fires • Increased stand-off range, decreased time-to-target • Eliminates hazards of high-explosives in the ship and unexploded ordnance on the battlefield

To provide increased payload power and reduce overall energy consumption in addition to providing other HM&E capability improvements, a significant and highly coordinated effort is required within the Naval ship HM&E research and development communities. The HM&E roadmap is an early effort to, among other things, communicate the requirements between Navy leadership and the technologists and engineers.

ANALYSIS

A Balanced Technology Portfolio

The U.S. Navy is actively developing and providing simpler, smarter, more affordable, and more capable ship's power systems with increased power density for many Surface Ship platforms. In order to meet the expanding challenges of increasing electrical power demands while reducing vulnerabilities associated with a dependence on foreign sources of petroleum, a balanced portfolio approach (Fig. 4) has been adopted to support strategic imperatives established by U.S. Navy leadership to achieve greater Navy-wide energy security. One of the ways the Surface Navy community is leading the drive toward energy reform and capitalizing on further reduction in total ownership costs (TOC) is through the development and early adoption of energy efficient enabling technologies that mitigate our reliance on fossil fuels.

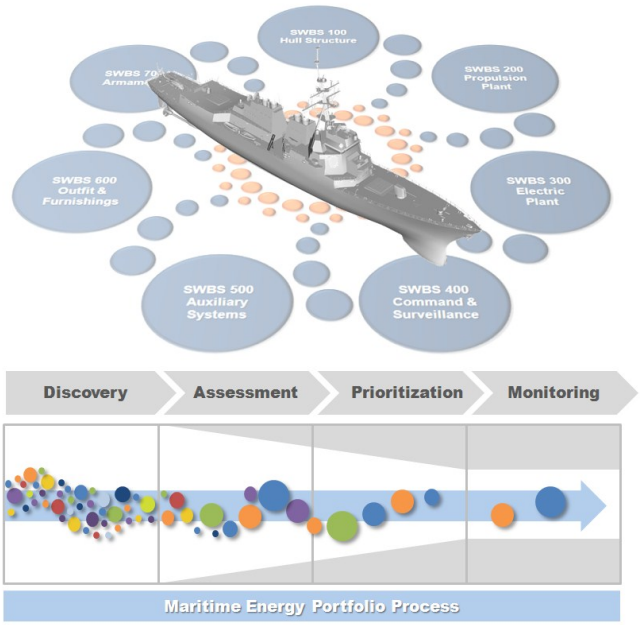

FIGURE 4 Maritime Energy Portfolio Process

Our international partners have gained experience with energy efficient technologies and integrated architectures. For example, the Royal Navy's acquisition of the Type 45 Destroyer with an IPS and the Type 23 Frigate powered by the Combined Diesel-Electric and Gas Turbine (CODLAG) architecture provides an important data point (Smith 2010). Similarly, the U.S. Navy gained experience with the acquisition of the Lewis and Clark Class (T-AKE) Dry Cargo/Ammunition Ship and the Combined Diesel-Electric or Gas Turbine (CODLOG) (also known as hybrid gas-turbine-electric drive) aboard the USS MAKIN ISLAND (LHD 8) Amphibious Assault Ship (Dalton, Mako, and Boughner 2010). The U.S. Navy is actively working across the Fleet to develop and transition innovative energy efficient technologies within its portfolio to transform the U.S. Navy's energy-security posture and pace threats facing the Fleet over the next several decades. As the portfolio of initiatives continues to expand, and is mapped to an integrated HM&E roadmap, technologies will be continuously revisited in an iterative process to ensure resource

investment decisions and technology development paths remain aligned with capability and operational energy requirements. This analytic-driven process will help to resolve competing frameworks (e.g. accelerating the adoption of new combat system capabilities versus the need to reduce total ownership costs), which have historically fostered short-term individual approaches to technology employment rather than longer-term sustainable solutions. In addition, a well constructed HM&E roadmap will identify requirements or needs that have very few if any developing technology solutions and those that have many. While this condition may be desired based on the relative importance of the needs, the HM&E roadmap will allow this analysis to take place consciously and openly. The output of the analysis and roadmap artifacts will serve as a unifying document between organizations to address future challenges in full alignment and provide a foundation for industry and academia to focus resources.

Redesign

The Operational Energy Requirement

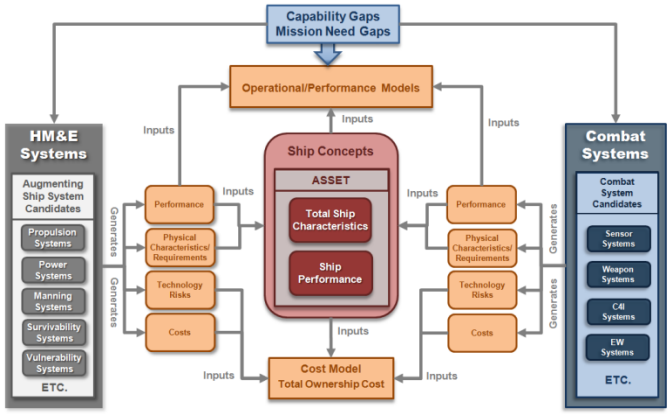

FIGURE 5 Balancing the Operational Energy Requirement

Historically, energy considerations have not played a primary role in the acquisition process. Generally, the focus on energy efficiency has been regarded as guidance as opposed to direction. As part of the HM&E Roadmap, a capability-based development process will be employed to define a portfolio for evaluation of new platform requirements (Fig 5). The concepts identified will outline a portfolio of alternatives that fulfill current and future mission and capability gaps, while meeting the needs, resource sponsor requirements, and acquisition community cost objectives. The process employed will also establish traceable links and direct relationships between the mission effectiveness associated with individual ship concepts, technology risks, and total ownership costs.

As energy policy has evolved as a national security issue, more emphasis is placed on operational energy efficiency, including the establishment of a central office within the Department of Defense (DoD) to provide guidance and oversight for Operational Energy Plans and Programs; summarized in program rating of DoN energy strategy and targets (Table 3). Recent progress has included an agreement from the DoD Joint Requirements Oversight Council (JROC) to selectively apply energy efficiency as a Key Performance Parameter (KPP). The energy efficiency KPP will include defining and utilizing the Fully Burdened Cost of Fuel (FBCF) in analyses for life cycle costs in acquisition decisions. Additionally, policies mandating energy efficiency considerations, consistent with mission needs, are being established for application during campaign analyses. As energy efficiency is incorporated into the DoD 5000.02 acquisition process instructions, these requirements will be reviewed as a component of overall Surface Ship TOC (Levac, Mondal, and Sturtevant 2010).

TABLE 3 Operational Energy Requirements

Naval Operational Energy Requirements	FY2012 Assistant Secretary of Defense for Operational Energy Plans and Programs Rating of DON Energy Strategy and Targets
Increase Alternatives Afloat	• By 2020, 50% of total DON energy consumption will come from alternative sources (GREEN)
Sail the Great Green Fleet	• DON will demonstrate a Green Strike Group in local operations by 2012 and sail it by 2016 (GREEN)
Increase Efficiency Afloat	• Current/near-term efforts, monitoring and measuring, Science & Technology, and legacy Fleet efforts (GREEN)
Energy Efficient Acquisition	• Evaluation of energy factors will be mandatory when awarding contracts (YELLOW)

In response to enabling energy efficient acquisition when awarding contracts, the U.S. Navy is developing a robust set of tools and methodologies to accurately predict TOC, conduct trade-off analyses, and calculate Return on Investment (ROI) and break even points in acquisition phase decision making that affect long-term life cycle cost objectives (Banfield 2008). Particularly in the area of Operations and Support (O&S), the U.S.

Navy has invested in enhancements to the Visibility and Management of Operating and Support Cost (VAMOSC) system to include more details and ship system level information. Recent VAMOSC updates include greater fidelity for fuel consumption data collected for the total ship, propulsion system, and ship power generating systems. VAMOSC data includes the Fleet Commander's monthly fuel report, which then applies the current price for the type of fuel, and is reported monthly to the U.S. Navy's Standard Accounting and Reporting System (STARS) database (Kunc 2004). This information allows cost analysts to conduct propulsion and power generation systems tradeoffs more accurately. VAMOSC improvements have enabled U.S. Navy analysts to quickly identify trends and relationships among O&S cost elements. To enhance visibility into TOC, the U.S. Navy jointly developed the Operating and Support Cost Analysis Model (OSCAM) in conjunction with the UK Ministry of Defense. OSCAM is a dynamic model that uses VAMOSC information and provides analysts a tool with rapid assessment of cost elements that drive costs and their relationship to ship operating profile, maintenance strategy, and support management policies (Curram and Sheman 2011). An optimized operational tempo for fuel saving operating procedures developed under the U.S. Navy's Energy Conservation Program saved nearly $100M in annual fuel costs (Carter 2009). This program provides U.S. Navy Surface Ships with energy saving strategies and techniques without impairing mission objectives. Additionally, analysts are using risk analyses to mitigate the uncertainty in fuel price and variability of inflation. A breakeven analysis of life cycle cost is conducted for surface ships to evaluate cost effectiveness of alternate propulsion and power generating systems, and sensitivity to fuel price and ship's operating profile. Disciplined cost analyses will provide U.S. Navy leadership a more complete perspective when determining the course of action for future acquisition programs.

Detailed costs and savings such as the above will need to be modeled accurately and used as some of the many inputs required to effectively prioritize the development plans laid out in the HM&E roadmap. Although in the early stages of development, a figure of merit (FOM) is being proposed to help guide which technology development paths are pursued. While the links between requirements and the technologies to fulfill those requirements are important to a successful roadmap, as much or more work needs to go into prioritization to complete the roadmap story. The complete roadmap story has to provide decision makers with plainly understandable criteria so that derived technical requirements can be prioritized. Only in this way can the complete requirements picture be communicated to allow the technologist to see the whole picture. In practice this differentiates between requirements that would be nice to meet for free and those requirements critical to mission needs.

TRANSFORMATION

An Energy Secure Fleet

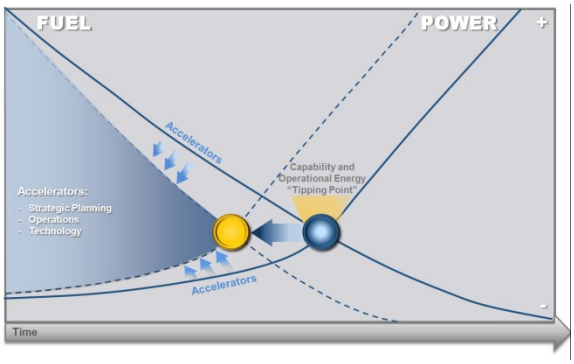

FIGURE 6 Capability Requirements Balanced with Operational Energy Requirements

Navigating complex energy security challenges requires disciplined strategic planning, operational changes, and innovative technology to drive transformation throughout the U.S. Navy Surface Fleet. Moving forward, ships must be able to quickly incorporate new mission capabilities that require increased electric power demand while also significantly reducing fossil fuel consumption (Fig. 6). The challenges of technology development and system integration increase with the need to reduce fuel consumption, balance mission requirements, and increase available electrical power. However, the adoption of innovative and energy efficient technologies outlined in an integrated HM&E Roadmap will help transform the U.S. Navy's energy posture and reach the capability and operational energy "tipping point" sooner. It is desirable to keep technological risk in the S&T domain as opposed to the acquisition community. This can be accomplished by leveraging investments in technologies capable of reducing fuel consumption, improving power conversion efficiency, and increasing installed power generation, while maintaining and increasing combat capability.

Beginning with the clear vision of an energy secure Fleet outlined by U.S. Navy leadership and cultural changes adopted by operational commanders, the U.S. Navy is beginning to embrace energy as a strategic resource (Winston 2011). To increase the adoption of energy efficient technologies and accelerate achievement of transformational goals, the U.S. Navy is also

establishing strategic technology partnerships throughout the federal government, academia, and with allied nations, including agreements with the newly established Advanced Research Project Agency – Energy (ARPA-E) within the U.S. Department of Energy (Bullis 2011).

TABLE 4 Major Tactical Energy Legislation and Mandates

Statute/Guidance	Description
U.S. Code - Section 138c	• Establishes Assistant Secretary of Defense for Operational Energy Plans and Programs (ASD(OEPP)) as the principal advisor to the Secretary, Deputy Secretary of Defense, and the Undersecretary for Defense for Acquisition Technology and Logistics and the principal policy official within the senior management of the DoD regarding operational energy
U.S. Forces – Afghanistan; Supporting the Mission with Operational Energy	• Establishes an office and provides direction to improve operational capabilities through changes in how Coalition Forces use energy
2010 Quadrennial Defense Review	• Asserts that DoD will fully implement the Energy KPP and fully burdened cost of fuel (FBCF) methodologies required by the NDAA 2009
2009 National Defense Authorization Act	• Requires analysis and force planning processes to consider the requirements for, and vulnerability of, fuel logistics • Requires a fuel efficiency Key Performance Parameter (KPP) in the requirements development processes for modification of existing or development of new fuel-consuming systems • Requires that life-cycle cost analysis for new systems include a calculation of the fully burdened cost of fuel (FBCF) during the Analysis of Alternatives (AoA), and evaluation of alternatives in acquisition program design trades
DoD Instruction 5000.02; Operation of the Defense Acquisition System	• Directs that AoAs assess alternative ways to improve energy efficiency
Manual for Operations of the Joint Capabilities Integration and Development System: CJCSI 3170.01G	• Establishes Energy Efficiency as a new, selectively-applied KPP

Finally, legislative, acquisition, and operational energy security mandates have been established (Table 4) to support U.S. Navy and broader DoD transformational objectives (Snider 2011).

When looking at the list of goals and mandates shown here, the logical next step is to produce plans to achieve the mandate objectives. The HM&E roadmap may drive transformational technologies to this end, but at a minimum it will make it easier to incorporate transformational technologies and also more apparent which technologies currently do not have a clear transition path. Although this might initially result in cuts to some developmental technologies, it can also record and broadcast them in a common format that can lead to recognition of future unanticipated uses. These new ideas would be integrated into the roadmap in an iterative process. Having readily available systems and technology availability dates and rough estimates of investment required could aid in transforming the way future ships are planned. Although much care is put into planning future ship classes, comprehensive technology development plans have not been available. Clearly expressed technical evaluations linked to the articulated requirements can produce a paradigm shift in the way expectations are set for new ship designs and planned modernizations. Although there will always be risk in technology development, the HM&E roadmap will communicate those risks transparently to all stakeholders.

CONCLUSION

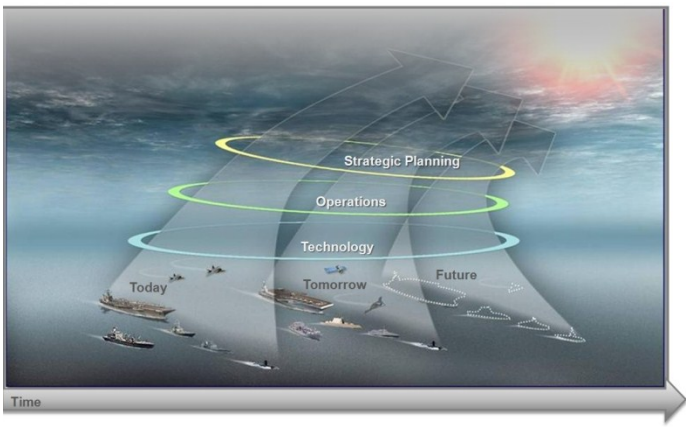

FIGURE 7 An Energy Secure Fleet

As outlined above, an HM&E roadmap will need to outline technologies available for future ship classes to ensure the Navy remains responsive to future naval capabilities, shipbuilding plans, current Fleet opportunities, and budgetary realities. An integrated roadmap for Surface Ships will be required to provide a more effective means to inform

resource investment and acquisition strategy decisions for critical science and technology, research and development, new ship construction, mid-life modernization, and sustainment programs.

It is important to note, the majority of the Navy's end strength of 2020 is already in the Fleet today. To afford the future Fleet, we need to operate and support our ships with significantly greater energy efficiency than we have in the past. Unless we radically change our approach and develop smarter solutions through the development of integrated plans unifying Combat Systems and HM&E technologies, the U.S. Navy faces the possibility of retiring ships well in advance of their design service lives. The mandate to reduce energy consumption while meeting increasing electrical power demands to pace the threat is a national imperative and the U.S. Navy has taken the lead among our military services to set aggressive goals and implement plans to achieve these objectives. Reducing petroleum consumption has national security as well as budgetary implications for the U.S. Navy. Becoming more energy efficient increases ship endurance, enhances operational flexibility, and supports forward presence while reducing the vulnerability inherent in a long supply line. If the U.S. Navy is to build and sustain an affordable energy secure Fleet, there is a need to accelerate the development and fielding of new energy efficient technologies. Executing a comprehensive plan to introduce these technologies will require an integrated systems engineering methodology to develop a comprehensive HM&E Roadmap that supports sound decisions and strong returns on those investments.

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the contributions made to the body of knowledge across the U.S. Navy which has led the way for energy reform, increasing warfighting capability, both strategically and tactically. The authors would also like to recognize the Office of Naval Research (ONR) for investments in scientific research and technology development and the innovative concepts delivered by Naval Surface Warfare Centers (NSWC). Finally, the support from our colleagues at the Naval Sea Systems Command (NAVSEA) and Herren Associates, Inc. is gratefully acknowledged.

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